

## DESCRIPTION

Method for Manufacturing Homeotropic Alignment Liquid Crystal Film, Homeotropic Alignment Liquid Crystalline Composition and Homeotropic Alignment Liquid Crystal Film

## BACKGROUND OF THE INVENTION

## Field of the Invention

The present invention relates to a method for manufacturing a homeotropic alignment liquid crystal film. Moreover, the present invention relates to a homeotropic alignment liquid crystalline composition and a method for manufacturing a homeotropic alignment liquid crystal film using the homeotropic alignment liquid crystalline composition. Furthermore, the present invention relates to a homeotropic alignment liquid crystal film and an optical film obtained by the above-mentioned manufacturing method. Moreover, the present invention relates to a visual display, such as a liquid crystal display, an organic EL display, a PDP (plasma display panel), etc. using the above-mentioned optical film. A homeotropic alignment liquid crystal film may be used as a retardation film, a viewing angle compensating film, an optical compensating film, and an elliptically polarization film independently or in combination with other optical films.

## Description of the Prior Art

When the major axis of a molecule of liquid crystal phase is substantially vertical to a substrate that forms thin film (liquid crystal phase) on the average, homeotropic alignment of a liquid crystal compound is given. Since substances that spontaneously provide homeotropic alignment are hardly known, a vertical alignment agent is generally used in order to acquire such alignment. A nematic liquid crystal compound is known, for example, as a liquid crystal compound that can give homeotropic alignment by vertical alignment agent. Such an outline in connection with an alignment technology of liquid crystal compound is indicated in Chemical Review 44 (Surface Reforming, edited by Chemical Society of Japan, pages 156-163).

Various kinds of organic or inorganic alignment agents are known as vertical alignment agents that can homeotropically align the above-mentioned liquid crystal compounds, and many of alignment agents used commonly are designed so that it may act effectively on a glass substrate.

As an organic alignment agent commonly used, for example, lecitin, silanes type surface active agent, n-octadecyl triethoxy silane, titanates type surface active agent, pyridinium salts type high molecular surface active agent, hexadecyl trimethyl ammonium halide, or chromium complex may be mentioned. After these organic alignment agents are

dissolved in suitable volatile solvents in which active ingredient is in a very small amount (typically less than 1%), and coated by a spin coating or other well-known coating methods on a substrate, subsequently the volatile solvent is evaporated to give a thin film of organic alignment agent on the glass substrate. These organic alignment agents are compounds characterized by having polar end groups considered to be drawn onto polar glass surface and linear alkyl chains with non-polarity vertically arranged to glass surface, and thus the agents have the liquid crystal compounds form homeotropic alignment on such a glass surface.

Moreover as inorganic alignment agents, for example, compounds coated by vapor deposition of  $\text{SiO}_x$  or  $\text{In}_2\text{O}_3/\text{SnO}_2$  at vertical angle onto a glass substrate are known, and they homeotropically align a liquid crystal compounds. In addition, polyimide films with alkyl side chain are also used as homeotropic alignment films for a liquid crystal display.

However, all of the above-mentioned alignment agents commonly used provides homeotropic alignment of liquid crystal compound only on glass substrate, and does not act effectively in alignment on substrates consisting of polymer substances such as plastic films and sheet plastics. A surface of a substrate consisting of a polymer substance may be presumed to have poor affinity to polar end groups of commonly used alignment agents described above, and as a result generally

does not show homeotropic alignment at all, or shows very poor alignment. Moreover, although a high temperature treatment is required for formation of polyimide film with alkyl side chain, transparent plastic films that have durability to conditions in which polyimide alignment films are baked, and that further may be used in an optical use are hardly known.

#### SUMMARY OF THE INVENTION

The first object of the present invention is providing a manufacturing method of a homeotropic alignment liquid crystal film that can form homeotropic alignment of a liquid crystal polymer on a substrate without using vertical alignment film. Moreover, other object of the present invention is providing a homeotropic alignment liquid crystal film obtained by the above-mentioned manufacturing method. Still other object of the present invention is providing an optical film having a homeotropic alignment liquid crystal film layer without vertical alignment film on a substrate, and a visual display using the above-mentioned optical film.

Since the side chain type liquid crystal polymer forms a film on the substrate without using the vertical alignment film,  $T_g$  of the liquid crystal film is designed low. However, the liquid crystal film is expected improvement in durability for being used as a liquid crystal display etc.

By these reasons, the other object of the present invention is providing a homeotropic alignment liquid crystalline composition that can form a homeotropic alignment liquid crystal film excellent in durability on a substrate without using a vertical alignment film. Moreover, other object of the present invention is providing a manufacturing method of a homeotropic alignment liquid crystal film using the homeotropic alignment liquid crystalline composition. Moreover, still other object of the present invention is providing a homeotropic alignment liquid crystal film obtained by the above-mentioned manufacturing method. Still more other object of the present invention is providing an optical film that has a homeotropic alignment liquid crystal film layer without having a vertical alignment film on a substrate, and a visual display using the above-mentioned optical film.

The present inventors performed wholehearted research in order to solve the above-mentioned problems and found out that the above-mentioned objects of the present invention can be attained as shown below.

The present invention attaining the above described first object of the present invention relates to a method for manufacturing a homeotropic alignment liquid crystal film, wherein a side chain type liquid crystal polymer comprising a monomer unit (a) containing a liquid crystalline fragment side chain and a monomer unit (b) containing a non-liquid

crystalline fragment side chain is coated on a substrate on which a vertical alignment film is not prepared, and the liquid crystal polymer is fixed while maintaining an alignment state after the liquid crystal polymer is homeotropically aligned in liquid crystal state.

In the present invention, homeotropic alignment of a liquid crystal polymer is realized using a side chain type liquid crystal polymer comprising a monomer unit (a) containing liquid crystalline fragment side chain, and a monomer unit (b) containing non-liquid crystalline fragment side chain as a liquid crystal polymer, without using a vertical alignment film. The side chain type liquid crystal polymer of the present invention has a monomer unit (b) containing non-liquid crystalline fragment side chain that has alkyl chain etc., other than a monomer unit (a) containing liquid crystalline fragment side chain that is contained in conventional side chain type liquid crystal polymer. It can be presumed that even without a use of vertical alignment film the side chain type liquid crystal polymer will be in liquid crystal state, for example, by heat treatment to form a nematic liquid crystal phase by action of the monomer unit (b) containing non-liquid crystalline fragment side chain. Subsequently, after heat is removed, it is vitrified to give a homeotropic alignment liquid crystal film in which a homeotropically aligned liquid crystal polymer layer is fixed.

In the manufacturing method of the above-mentioned homeotropic alignment liquid crystal film, various materials may be used such as polymer substance, glass substrate and metal as a substrate. Moreover, a polymer substance is used in the form of a sheet plastic or a plastic film. There is no limitation in the kind of substrate used for the manufacturing method of the present invention, and a glass substrate, a polymer substance and a metal may be used without any limitation especially, and the polymer substance may be used in the form of a sheet plastic or a plastic film.

Moreover, the present invention relates to a homeotropic alignment liquid crystal film obtainable by the above-mentioned manufacturing method.

In addition, the present invention relates to an optical film wherein a homeotropic alignment liquid crystal film layer in which a liquid crystal polymer is homeotropically aligned is prepared on a substrate without vertical alignment layer.

According to the present invention, an optical film having a layer in which a liquid crystal polymer is homeotropically aligned may be provided without vertical alignment film. The above-mentioned optical film is realized using, as a liquid crystal polymer, a side chain type liquid crystal polymer comprising a monomer unit (a) containing liquid crystalline fragment side chain and a monomer unit (b) containing non-liquid crystalline fragment side chain.

Moreover, the present invention relates to a visual display applying the above-mentioned optical film.

The present invention attaining the above described other purpose of the present invention relates to a homeotropic alignment liquid crystalline composition comprising a side chain type liquid crystal polymer being able to form a homeotropic alignment liquid crystal layer on a substrate on which a vertical alignment film is not prepared and a photopolymerizable liquid crystal compound.

Besides the side chain type liquid crystal polymer the photopolymerizable liquid crystal compound contained in the above-mentioned homeotropic alignment liquid crystalline composition of the present invention may be homeotropically aligned, with the side chain type liquid crystal polymer, by being made a liquid crystal state with heat treatment, for example, to obtain a nematic liquid crystal layer. After that, the photopolymerizable liquid crystal compound further may be polymerized or cross-linked to increase the durability of homeotropic alignment liquid crystal film.

In the above-mentioned homeotropic alignment liquid crystalline composition, it is preferable that a side chain type liquid crystal polymer is a side chain type liquid crystal polymer comprising a monomer unit (a) containing liquid crystalline fragment side chain and a monomer unit (b) containing non-liquid crystalline fragment side chain.



The above-mentioned side chain type liquid crystal polymer may form a homeotropic alignment of liquid crystal polymer, without using a vertical alignment film. The side chain type liquid crystal polymer has a monomer unit (b) containing non-liquid crystalline fragment side chain having alkyl chain etc. other than a monomer unit (a) containing liquid crystalline fragment side chain contained in usual side chain type liquid crystal polymer. It can be presumed that even without a use of vertical alignment film the side chain type liquid crystal polymer will be in liquid crystal state, for example, by heat treatment to form a nematic liquid crystal phase by action of the monomer unit (b) containing non-liquid crystalline fragment side chain.

Moreover the present invention relates to a method for manufacturing a homeotropic alignment liquid crystal film, wherein the homeotropic alignment liquid crystalline composition according to claim 7 or 8 is coated on a substrate on which a vertical alignment film is not prepared subsequently the homeotropic alignment liquid crystalline composition is homeotropically aligned in liquid crystal state and is applied an optical irradiation after fixed in a state of alignment state being maintained.

After the above-mentioned liquid crystalline composition is homeotropically aligned, without using vertical alignment film, heat is removed and the composition

is vitrified to obtain a fixed liquid crystal polymer layer homeotropically aligned. Subsequently a homeotropic alignment liquid crystal film with excellent durability is obtained by polymerizing or cross-linking the photopolymerizable liquid crystal compound with optical irradiation.

In the manufacturing method of the above-mentioned homeotropic alignment liquid crystal film, various materials may be used such as polymer substance, glass substrate and metal as a substrate. Moreover, a polymer substance is used in the form of a sheet plastic or a plastic film. There is no limitation in the kind of substrate used for the manufacturing method of the present invention, and a glass substrate, a polymer substance and a metal may be used without any limitation especially, and the polymer substance may be used in the form of a sheet plastic or a plastic film.

Moreover, the present invention relates to a homeotropic alignment liquid crystal film obtainable by the above-mentioned manufacturing method.

The present invention also relates to an optical film, wherein a homeotropic alignment film layer in which the homeotropic alignment liquid crystal compound according to claim 7 or 8 is homeotropically aligned and fixed, is prepared on a substrate without a vertical alignment film.

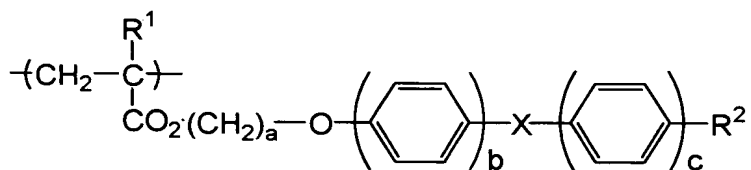
Furthermore, the present invention relates to a visual

display applying the above-mentioned optical film.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

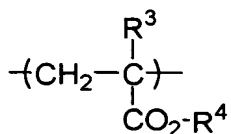
As a liquid crystal polymer that provides homeotropic alignment in the present invention, for example, a side chain type liquid crystal polymer comprising a monomer unit (a) containing liquid crystalline fragment side chain and a monomer unit (b) containing non-liquid crystalline fragment side chain is used.

As the above-mentioned monomer unit (a) having a side chain with nematic liquid crystalline, for example, a monomer unit represented by the following general formula (a) may be mentioned.

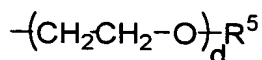


(where,  $\text{R}^1$  is a hydrogen atom or a methyl group,  $a$  is a positive integer of 1 to 6,  $\text{X}^1$  is  $\text{-CO}_2\text{-}$  group or  $\text{-OCO-}$  group,  $\text{R}^2$  is a cyano group, an alkoxy group with 1 to 6 carbon, fluoro group or alkyl group with 1 to 6 carbon, and  $b$  and  $c$  are integers of 1 or 2 respectively.)

Moreover, as a monomer unit (b) having linear side chain, for example, a monomer unit represented by the following general formula (b) may be mentioned.



(where,  $\text{R}^3$  is a hydrogen atom or a methyl group,  $\text{R}^4$  is an alkyl group with 1 to 22 carbon, a fluoroalkyl group with 1 to 22 carbon, or a monomer unit represented by the general formula (c):



where,  $d$  is a positive integer of 1 to 6, and  $\text{R}^5$  is an alkyl group with 1 to 6 carbon).

Besides, the ratio of the monomer unit (a) and the monomer unit (b) is not limited in particular. Although the ratio varies also according to the kinds of monomer units, since the side chain type liquid crystal polymer does not show liquid crystal monodomain alignment property when the ratio of the monomer unit (b) increases, the percentage is preferably defined in a range of  $(b) / \{(a) + (b)\} = 0.01$  to  $0.8$  (mole ratio), more preferably  $0.1$  to  $0.5$ .

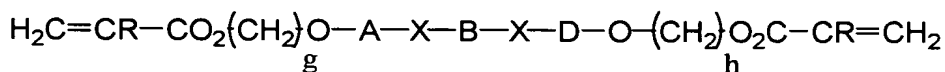
A weight average molecular weight of the above-mentioned side chain type liquid crystal polymer is preferably in a range of  $2000$  to  $100000$ . Performance as a liquid crystal polymer is demonstrated by adjusting the weight average molecular weight into this range. The weight average molecular weight is preferably no less than  $2500$ , because the film forming property of an alignment layer shows a tendency

of being poor when the weight average molecular weight of the side chain type liquid crystal polymer is too small. On the other hand, the weight average molecular weight is preferably no more than 50000 because if the weight average molecular weight is too large the polymer has a tendency of forming a poor alignment state caused by a poor alignment property as liquid crystal.

In addition, the side chain type liquid crystal polymer may be prepared by copolymerizing acrylic type monomer or methacryl type monomer corresponding to the above-mentioned monomer unit (a) and monomer unit (b). The above-mentioned monomer corresponding to the monomer unit (a) and the monomer unit (b) is synthesized by conventionally well-known methods. The copolymer may be prepared according to common polymerizing methods of acrylic type monomers, such as a radical polymerizing method, a cationic polymerizing method and an anionic polymerizing method. In addition, when a radical polymerization method is applied, various kinds of polymerization initiators may be used. Among these, initiators having a middle-ranged decomposition temperature, neither too high nor too low, such as azobisisobutyronitrile and benzoyl peroxide, may be preferably used.

As a photopolymerizable liquid crystal compound that may be added to the above-mentioned side chain type liquid crystal polymer, a liquid crystalline compound with nematic

liquid crystalline property that has at least one unsaturated double bond as photopolymerizable functional groups, such as acryloyl group or methacryloyl group may be preferably used. As the photopolymerizable liquid crystal compound, acrylates and methacrylates used as the above-mentioned monomer unit (a) may be mentioned. As a photopolymerizable liquid crystal compound, in order to increase durability, a compound having two or more photopolymerizable functional groups is preferable. As such a photopolymerizable liquid crystal compound, a cross-linked type nematic liquid crystalline monomer, for example, represented by the following general formula may be mentioned.



(where, R is a hydrogen atom or a methyl group, A and D are independently 1,4-phenylene group or 1,4-cyclohexylene group respectively, X is independently -COO- group, -OCO- group or -O- group respectively, B is 1,4-phenylene group, 1,4-cyclohexylene group, 4,4'-biphenylene group or 4,4'-bicyclohexylene group, and g and h are independently integers of 2 to 6 respectively).

The ratio of a photopolymerizable liquid crystal compound and a side chain type liquid crystal polymer in a liquid crystalline composition does not have particular limitation, and the ratio is suitably specified in

consideration of the durability of the homeotropic alignment liquid crystal film obtained etc.

Usually, the ratio is preferably (photopolymerizable liquid crystal compound): (side chain type liquid crystal polymer) (weight ratio) = 0.1: 1 to 30: 1, more preferably 0.5: 1 to 20: 1, still more preferably 1: 1 to 10: 1.

Photo polymerization initiator is usually contained in the above-mentioned liquid crystalline composition. Various kinds of photo polymerization initiator may be used without any particular limitation. As a photo polymerization initiator, for example, Irgacure 907, the said 184, the said 651, the said 369 etc. by Ciba Specialty Chemicals, may be mentioned. Photo polymerization initiator is added in an amount within a range that does not disturb the homeotropic alignment property of the liquid crystalline composition, in consideration of the kind of the photopolymerization liquid crystal compound and the compounding ratio of the liquid crystalline composition etc. Usually, the amount is in a range of preferably about 0.5 to 30 weight parts to photopolymerizable liquid crystal compound 100 weight parts, and more preferably 3 to 15 weight parts.

A substrate on which the side chain type liquid crystal polymer or the liquid crystalline composition is coated may be of any form of a glass substrate, a metallic foil, a sheet plastic, or a plastic film. Thickness of the substrate is

usually about 10 to 1000  $\mu\text{m}$ .

No limitation exists for a plastic film if the plastic film does not show any change at the temperature at which the film is treated during alignment. As a suitable film, for example, a film made of transparent polymers, such as polyester type polymers, such as polyethylene terephthalate and polyethylenenaphthalate; cellulose type polymers, such as diacetyl cellulose and triacetyl cellulose; polycarbonate type polymers; acrylic type polymers, such as polymethylmethacrylate may be mentioned. In addition a film made of transparent polymers, such as styrene type polymers, such as polystyrene and acrylonitrile-styrene copolymer; olefin type polymers, such as polyethylene, polypropylene; polyolefin having cyclic or norbornene structure, ethylene-propylene copolymer; vinyl chloride type polymers; amide type polymers, such as nylon and aromatic polyamide may be mentioned. Moreover, a film made of transparent polymers, such as imide type polymers, sulfone type polymers, polyether sulfone type polymers, polyether ether ketone type polymers, polyphenylene sulfide type polymers, vinyl alcohol type polymers, vinylidene chloride type polymers, vinyl butyral type polymers, allylate type polymers, polyoxymethylene type polymers, epoxy type polymers and blended polymers of the above described polymers may be mentioned. In these, a plastic film with high hydrogen bond



is preferable.

Besides, as a metal film, for example, a film made of aluminum etc. may be mentioned.

Especially as a plastic film, a plastic film comprising polymer substance having norbornene structure, such as Zeonor (brand name, by Zeon Corporation), Zeonex (brand name, by Zeon Corporation), and ARTON (brand name, by JSR Corporation), has optically excellent characteristics. Since these polymer substance (plastic film) has very small optical anisotropy, the alignment liquid crystal film layer of the above-mentioned side chain type liquid crystal polymer or of liquid crystalline composition formed on the plastic film may be used for optical films in its natural condition, such as optical compensating use of liquid crystal display, as a homeotropic alignment retardation film, without transferring the alignment liquid crystal film layer to another plastic film. Besides, the above-mentioned side chain type liquid crystal polymer or the alignment liquid crystal film layer of liquid crystalline composition formed on the plastic film or metal films, such as aluminum foil, having optical anisotropy is transferred directly or via adhesives onto a plastic film that has transparency and low optical anisotropy, such as a film having norbornene structure and cellulose triacetate, after forming the above-mentioned side chain type liquid crystal polymer or liquid crystalline

composition into an alignment liquid crystal film. Thus the above mentioned liquid crystal polymer or the alignment liquid crystal film layer may be used for optical films, such as a compensating film.

As a method by which the above-mentioned side chain type liquid crystal polymer or liquid crystalline composition is coated onto a substrate, a solution coating method using a solution of the side chain type liquid crystal polymer or the liquid crystalline composition in solvents, or a molten coating method using a molten liquid crystal polymer or liquid crystalline composition may be mentioned. In these two methods, a method in which a solution of the side chain type liquid crystal polymer or the liquid crystalline composition is coated onto a supporting substrate is preferable, using the above-mentioned solution coating method.

As a solvent used when a solution is prepared, although a situation varies with kinds of a side chain type liquid crystal polymer or a liquid crystalline composition, or a substrate and it cannot be generally discussed, but usually, halogenated hydrocarbons, such as chloroform, dichloro methane, dichloroethane, tetrachloroethane, trichloroethylene, tetrachloroethylene and chlorobenzene; phenols, such as phenol and parachlorophenol; aromatic hydrocarbons, such as benzene, toluene, xylene, methoxy benzene, 1,2-dimethoxy benzene; as well as, acetone, ethyl

acetate, tert-butyl alcohol, glycerin, ethylene glycol, triethylene glycol, ethylene glycol monomethyl ether, diethylene glycol dimethyl ether, ethyl cellosolve, butyl cellosolve, 2-pyrrolidone, N-methyl-2-pyrrolidone, pyridine, triethyl amine, tetrahydrofuran, dimethyl formamide, dimethyl acetamide, dimethyl sulfoxide, acetonitrile, butyronitrile, carbon disulfide, etc. may be used. Although it cannot be generally discussed since a concentration of solution is dependent on the solubility of the side chain type liquid crystal polymer or the liquid crystalline composition used, and on thickness of a film of the alignment liquid crystal film finally obtained, usually, the concentration is in a range of 3 to 50 weight percent, preferably of 7 to 30 weight percent.

The thickness of the coated homeotropic alignment liquid crystal film layer, comprising the coated above-mentioned side chain type liquid crystal polymer or liquid crystalline composition, is preferably 1 to 10  $\mu\text{m}$ . In addition, since the film thickness is mostly determined at the stage of coating on a substrate, especially in the case where the film thickness of the homeotropic alignment liquid crystal film needs to be controlled precisely and accurately, the control of a concentration of the solution and a film thickness of the film to be coated etc. should be carried out especially with care.

As a method of coating the solution of the side chain type liquid crystal polymer or the liquid crystalline composition adjusted to a desired concentration using the above-mentioned solvent, for example, a spin coating method and a bar coating method etc. may be employed. After coated, the solvent is removed and a liquid crystal polymer layer is formed on the substrate. Conditions of removing the solvent are not especially limited, and if the solvent is removed in general, and if the liquid crystal polymer layer does not flow around or does not flow off, any conditions may be adopted. Usually, methods such as drying at room temperature, drying in a drying furnace and heating on hot plate are adopted to remove the solvent.

Subsequently, the side chain type liquid crystal polymer layer or the liquid crystalline composition layer formed on the supporting substrate is changed into liquid crystal state, and homeotropically aligned. For example, heat treatment is performed so that liquid crystal polymer may be in a liquid crystal temperature range, and homeotropically aligned in the state of liquid crystal. Heat treatment may be performed by the same method as the above-mentioned drying method. Although it cannot be generally discussed about heat treating temperature since the heat treating temperature varies with the kinds of the side chain type liquid crystal polymer or the liquid crystalline composition and the supporting

substrate to be used, the range is usually 60 to 300°C, preferably 70 to 200°C. Besides, although heat treatment period is not generally discussed since it varies with the heat-treating temperature and the side chain type liquid crystal polymer or the liquid crystalline composition to be used or kinds of the substrate, it is in general chosen in a range of 10 seconds to 2 hours, preferably of 20 seconds to 30 minutes. When the heat treatment period is shorter than 10 seconds, homeotropic alignment may not be sufficiently formed.

Cooling operation is performed after heat treatment. Taking the homeotropic alignment liquid crystal film out of heating atmosphere in the heat treatment operation after the heat treatment performs cooling operation. Besides, compulsive cooling by air or by water etc. may be performed. By cooling the layer lower than the glass transition temperature of the liquid crystal polymer, alignment of the homeotropic alignment layer of the above-mentioned liquid crystal polymer or liquid crystalline composition is fixed.

In a liquid crystalline composition, a photopolymerizable liquid crystal compound is polymerized or cross-linked to fix the photopolymerizable liquid crystal compound by an optical irradiation that is applied to the homeotropic liquid crystal alignment layer fixed in this way. Thus, a homeotropic alignment liquid crystal film with

improved durability is obtained. Optical irradiation is performed by, for example, ultraviolet irradiation. In order to fully promote the reaction, the ultraviolet irradiation treatment is preferably carried out in inert gas atmosphere. Usually a high-pressure mercury ultraviolet lamp that has illumination of about 80 to 160 mW/cm<sup>2</sup> is used in general. Lamp of another kind, such as meta-halide UV lamp and incandescence bulb may also be used. In addition, the liquid layer surface temperature at the time of ultraviolet irradiation is adjusted suitably using cooling processing, such as of cold mirror, of water cooling and others or of making line velocity higher so that the layer surface temperature may become within a range of liquid crystal temperature.

Thus, a thin film of the side chain type liquid crystal polymer or the liquid crystalline composition is formed and an alignment liquid crystal film is obtained, which is homeotropically aligned and is fixed in a state of homeotropic alignment. The alignment liquid crystal layer concerned has molecules aligned in the same direction. Therefore, since it is common knowledge that freezes of aligning vector of this alignment liquid crystal layer, or stabilization and preservation of the anisotropic physical properties are attained. In such a thin film, these optical properties are confirmed and the film is used for various kinds of uses.

The above-mentioned alignment liquid crystal layer is a thin film that has a positive uniaxial birefringence.

Alignment of homeotropic alignment liquid crystal obtained as mentioned above is quantified by measuring an optical retardation of the liquid crystal layer at an angle inclined from vertical incident angle. In homeotropic alignment liquid crystal film, this retardation value is symmetrical to vertical incidence. Several sorts of methods may be used for measuring an optical retardation, for example, automatic birefringence measuring equipment (by "Oak") and polarization microscope (by OLYMPUS OPTICAL CO., LTD.) may be used. This homeotropic alignment liquid crystal film is observed black through crossed Nicol polarizer.

The homeotropic alignment liquid crystal film thus obtained may be used by being removed from a substrate or may be used as an alignment liquid crystal layer formed on a substrate as it is without being removed.

The homeotropic alignment liquid crystal film of the present invention may be independently used as a retardation film (a retardation plate), a viewing angle compensating film and a compensating film. On the occasion of practical use, it may be used as an optical film laminated together with other optical layers, such as a polarization plate. For example, when a homeotropic alignment liquid crystal film is manufactured using a retardation film uniaxially aligned,

a retardation film with wide viewing angle may be obtained. A display characteristic of a liquid crystal display, especially a viewing angle characteristic may be remarkably improved by applying this film to an STN type liquid crystal display.

A polarization plate is used for an optical film applied to visual display, such as a liquid crystal display. Polarizing plate usually has protective films on one side or both sides of a polarizer. A polarizer is not limited especially but various kinds of polarizer may be used. As a polarizer, for example, a film that is uniaxially stretched after having dichromatic substances, such as iodine and dichromatic dye, absorbed to hydrophilic high molecular weight polymer films, such as polyvinyl alcohol type film, partially formalized polyvinyl alcohol type film, and ethylene-vinyl acetate copolymer type partially saponified film; poly-ene type alignment films, such as dehydrated polyvinyl alcohol and dehydrochlorinated polyvinyl chloride, etc. may be mentioned. In these, a polyvinyl alcohol type film on which dichromatic materials (iodine, dyes) is absorbed and aligned after stretched is suitably used. Although thickness of polarizer is not especially limited, the thickness of about 5 to 80  $\mu\text{m}$  is commonly adopted.

A polarizer that is uniaxially stretched after a polyvinyl alcohol type film dyed with iodine is obtained by



stretching a polyvinyl alcohol film by 3 to 7 times the original length, after dipped and dyed in aqueous solution of iodine. The film may also be dipped in aqueous solutions, such as boric acid and potassium iodide, if needed. Furthermore, before dyeing, the polyvinyl alcohol type film may be dipped in water and rinsed if needed. By rinsing polyvinyl alcohol type film with water, effect of preventing un-uniformity, such as unevenness of dyeing, is expected by making polyvinyl alcohol type film swelled in addition that also soils and blocking inhibitors on the polyvinyl alcohol type film surface may be washed off. Stretching may be applied after dyed with iodine or may be applied concurrently, or conversely dyeing with iodine may be applied after stretching. Stretching is applicable in aqueous solutions, such as boric acid and potassium iodide, and in water bath.

As a protective film prepared in one side or both sides of the above-mentioned polarizer, materials with outstanding transparency, mechanical strength, heat stability, moisture cover property, isotropy, etc. may be preferable. As materials of the above-mentioned protective film, for example, polyester type polymers, such as polyethylene terephthalate and polyethylenenaphthalate; cellulose type polymers, such as diacetyl cellulose and triacetyl cellulose; acrylics type polymer, such as poly methylmethacrylate; styrene type polymers, such as polystyrene and acrylonitrile-styrene

copolymer (AS resin); polycarbonate type polymer may be mentioned. Besides, as examples of the polymer forming a protective film, polyolefin type polymers, such as polyethylene, polypropylene, polyolefin that has cyclo- type or norbornene structure, ethylene-propylene copolymer; vinyl chloride type polymer; amide type polymers, such as nylon and aromatic polyamide; imide type polymers; sulfone type polymers; polyether sulfone type polymers; polyether-ether ketone type polymers; poly phenylene sulfide type polymers; vinyl alcohol type polymer; vinylidene chloride type polymers; vinyl butyral type polymers; allylate type polymers; polyoxymethylene type polymers; epoxy type polymers; or blend polymers of the above-mentioned polymers may be mentioned. In addition, a film comprising resins of heat curing type or ultraviolet curing type, such as acrylics type, urethane type, acrylics urethane type and epoxy type and silicone type type may be mentioned. Generally, thickness of the protective film is no more than 500  $\mu\text{m}$ , preferably 1 to 300  $\mu\text{m}$  and more preferably 5 to 200  $\mu\text{m}$ .

As a protective film, cellulose type polymers, such as triacetyl cellulose, is preferable by reason of polarization characteristics and durability etc. Especially triacetyl cellulose film is preferable. In addition, when protective film is prepared on both sides of the polarizer, the protective film consisting of the same polymer material may be used on

the front and the backside, or the protective films consisting of different polymer materials etc. may be used. The above-mentioned polarizer and the protective film are usually adhered via an aqueous pressure sensitive adhesive etc. As an aqueous pressure sensitive adhesive, polyvinyl alcohol type adhesives, gelatin type adhesives, vinyl type latex type adhesives, aqueous polyurethane adhesives, aqueous polyester adhesives, etc. may be mentioned.

As the above-mentioned protective film, a film with a hard coat layer and various processing aiming for antireflection, sticking prevention and diffusion or anti glare may be used.

A hard coat processing is applied for the purpose of protecting the surface of the polarization plate from damage, and this hard coat film may be formed by a method in which, for example, a curable coated film with excellent hardness, slide property etc. is added on the surface of the protective film using suitable ultraviolet curable type resins, such as acrylic type and silicone type resins. Antireflection processing is applied for the purpose of antireflection of outdoor daylight on the surface of a polarization plate and it may be prepared by forming an antireflection film according to the conventional method etc. Besides, a sticking prevention processing is applied for the purpose of adherence prevention with adjoining layer.

In addition, an anti glare processing is applied in order to prevent a disadvantage that outdoor daylight reflects on the surface of a polarization plate to disturb visual recognition of transmitting light through the polarization plate, and the processing may be applied, for example, by giving a fine concavo-convex structure to a surface of the protective film using, for example, a suitable method, such as rough surfacing treatment method by sandblasting or embossing and a method of combining transparent fine particle. As a fine particle combined in order to form a fine concavo-convex structure on the above-mentioned surface, transparent fine particles whose average particle size is 0.5 to 50  $\mu\text{m}$ , for example, such as inorganic type fine particles that may have conductivity comprising silica, alumina, titania, zirconia, tin oxides, indium oxides, cadmium oxides, antimony oxides, etc., and organic type fine particles comprising cross-linked or non-cross-linked polymers may be used. When forming fine concavo-convex structure on the surface, the amount of fine particle used is usually about 2 to 50 weight part to the transparent resin 100 weight part that forms the fine concavo-convex structure on the surface, and preferably 5 to 25 weight part. An anti glare layer may serve as a diffusion layer (viewing angle expanding function etc.) for diffusing transmitting light through the polarization plate and expanding a viewing angle etc.

In addition, the above-mentioned antireflection layer, sticking prevention layer, diffusion layer, anti glare layer, etc. may be built in the protective film itself, and also they may be prepared as an optical layer different from the protective layer.

The above-mentioned polarization plate may be used as elliptically polarization plate or circularly polarization plate on which the retardation plate is laminated. A description of the above-mentioned elliptically polarization plate or circularly polarization plate will be made in the following paragraph. These polarization plates change linearly polarized light into elliptically polarized light or circularly polarized light, elliptically polarized light or circularly polarized light into linearly polarized light or change the polarization direction of linearly polarization by a function of the retardation plate. As a retardation plate that changes circularly polarized light into linearly polarized light or linearly polarized light into circularly polarized light, what is called a quarter wavelength plate (also called  $\lambda/4$  plate) is used. Usually, half-wavelength plate (also called  $\lambda/2$  plate) is used, when changing the polarization direction of linearly polarized light.

Elliptically polarization plate is effectively used to give a monochrome display without above-mentioned coloring by compensating (preventing) coloring (blue or yellow color)

produced by birefringence of a liquid crystal layer of a super twisted nematic (STN) type liquid crystal display.

Furthermore, a polarization plate in which three-dimensional refractive index is controlled may also preferably compensate (prevent) coloring produced when a screen of a liquid crystal display is viewed from an oblique direction. Circularly polarization plate is effectively used, for example, when adjusting a color tone of a picture of a reflection type liquid crystal display that provides a colored picture, and it also has function of antireflection.

For example, a retardation plate may be used that compensates coloring and viewing angle, etc. caused by birefringence of various wavelength plates or liquid crystal layers etc. Besides, optical characteristics, such as retardation, may be controlled using laminated layer with two or more sorts of retardation plates having suitable retardation value according to each purpose. As retardation plates, birefringence films formed by stretching films comprising suitable polymers, such as polycarbonates, norbornene type resins, polyvinyl alcohols, polystyrenes, polymethyl methacrylates, polypropylene; polyallylates and polyamides; oriented films comprising liquid crystal materials, such as liquid crystal polymer; and films on which an alignment layer of a liquid crystal material is supported may be mentioned. The above-mentioned homeotropic alignment

liquid crystal film may be used as such retardation plate.

Besides, the above-mentioned homeotropic alignment liquid crystal film is laminated onto polarization plate as a viewing angle compensating film to be used as a wide viewing angle polarization plate. A viewing angle compensating film is a film for extending viewing angle so that a picture may look comparatively clearly, even when it is viewed from an oblique direction not from vertical direction to a screen.

As such a viewing angle compensating retardation plate, in addition, a film having birefringence property that is processed by uniaxial stretching or orthogonal bidirectional stretching and a bidirectionally stretched film as inclined orientation film etc. may be used. As inclined orientation film, for example, a film obtained using a method in which a heat shrinking film is adhered to a polymer film, and then the combined film is heated and stretched or shrunk under a condition of being influenced by a shrinking force, or a film that is oriented in oblique direction may be mentioned. The viewing angle compensating film is suitably combined for the purpose of prevention of coloring caused by change of visible angle based on retardation by liquid crystal cell etc. and of expansion of viewing angle with good visibility.

Besides, a compensating plate in which an optical anisotropy layer consisting of an alignment layer of liquid crystal polymer, especially consisting of an inclined

alignment layer of discotic liquid crystal polymer is supported with triacetyl cellulose film may preferably be used from a viewpoint of attaining a wide viewing angle with good visibility.

Besides, although there is especially no limitation about an optical layer laminated in practical use, for example, one or more optical layers that may be used for formation of liquid crystal display, such as a reflection plate and a semitransparent plate, etc. may be used. Especially, a reflection type polarization plate or a semitransparent type polarization plate in which a reflection plate or a semitransparent reflector is further laminated on an elliptically polarization plate or a circularly polarization plate, or a polarization plate in which a brightness enhanced film is further laminated on the polarization plate may be mentioned.

A reflective layer is prepared on a polarization plate to give a reflection type polarization plate, and this type of plate is used for a liquid crystal display in which an incident light from a view side (display side) is reflected to give a display. This type of plate does not require built-in light sources, such as a backlight, but has an advantage that a liquid crystal display may easily be made thinner. A reflection type polarization plate may be formed using suitable methods, such as a method in which a reflective layer



of metal etc. is, if required, attached to one side of a polarization plate through a transparent protective layer etc.

As an example of a reflection type polarization plate, a plate may be mentioned on which, if required, a reflective layer is formed using a method of attaching a foil and vapor deposition film of reflective metals, such as aluminum, to one side of a matte treated protective film. Moreover, a different type of plate with a fine concavo-convex structure on the surface obtained by mixing fine particle into the above-mentioned protective film, on which a reflective layer of concavo-convex structure is prepared, may be mentioned. The reflective layer that has the above-mentioned fine concavo-convex structure diffuses incident light by random reflection to prevent directivity and glaring appearance, and has an advantage of controlling unevenness of light and darkness etc. Moreover, the protective film containing the fine particle has an advantage that unevenness of light and darkness may be controlled more effectively, as a result that an incident light and its reflected light that is transmitted through the film are diffused. A reflective layer with fine concavo-convex structure on the surface effected by a surface fine concavo-convex structure of a protective film may be formed by a method of attaching a metal to the surface of a transparent protective layer directly using, for example,

suitable methods of a vacuum evaporation method, such as a vacuum deposition method, an ion plating method, and a sputtering method, and a plating method etc.

Instead of a method in which a reflection plate is directly given to the protective film of the above-mentioned polarization plate, a reflection plate may also be used as a reflective sheet constituted by preparing a reflective layer on the suitable film for the transparent film. In addition, since a reflective layer is usually made of metal, it is desirable that the reflective side is covered with a protective film or a polarization plate etc. when used, from a viewpoint of preventing deterioration in reflectance by oxidation, of maintaining an initial reflectance for a long period of time and of avoiding preparation of a protective layer separately etc.

In addition, a semitransparent type polarizing plate may be obtained by preparing the above-mentioned reflective layer as a semitransparent type reflective layer, such as a half-mirror etc. that reflects and transmits light. A semitransparent type polarization plate is usually prepared in the backside of a liquid crystal cell and it may form a liquid crystal display unit of a type in which a picture is displayed by an incident light reflected from a view side (display side) when used in a comparatively well-lighted atmosphere. And this unit displays a picture, in a

comparatively dark atmosphere, using embedded type light sources, such as a back light built in backside of a semitransparent type polarization plate. That is, the semitransparent type polarization plate is useful to obtain of a liquid crystal display of the type that saves energy of light sources, such as a back light, in a well-lighted atmosphere, and can be used with a built-in light source if needed in a comparatively dark atmosphere etc.

The polarization plate with which a polarization plate and a brightness enhanced film are adhered together is usually used being prepared in a backside of a liquid crystal cell. A brightness enhanced film shows a characteristic that reflects linearly polarization light with a predetermined polarization axis, or circularly polarization light with a predetermined direction, and that transmits other light, when natural light by back lights of a liquid crystal display or by reflection from a back-side etc., comes in. The polarization plate, which is obtained by laminating a brightness enhanced film to a polarization plate, thus does not transmit light without the predetermined polarization state and reflects it, while obtaining transmitted light with the predetermined polarization state by accepting a light from light sources, such as a backlight. This polarization plate makes the light reflected by the brightness enhanced film further reversed through the reflective layer prepared

in the backside and forces the light re-enter into the brightness enhanced film, and increases the quantity of the transmitted light through the brightness enhanced film by transmitting a part or all of the light as light with the predetermined polarization state. The polarization plate simultaneously supplies polarized light that is difficult to be absorbed in a polarizer, and increases the quantity of the light usable for a liquid crystal picture display etc., and as a result luminosity may be improved. That is, in the case where the light enters through a polarizer from backside of a liquid crystal cell by the back light etc. without using a brightness enhanced film, most of the light, with a polarization direction different from the polarization axis of a polarizer, is absorbed by the polarizer, and does not transmit through the polarizer. This means that although influenced with the characteristics of the polarizer used, about 50 percent of light is absorbed by the polarizer, the quantity of the light usable for a liquid crystal picture display etc. decreases so much, and a resulting picture displayed becomes dark. A brightness enhanced film does not enter the light with the polarizing direction absorbed by the polarizer into the polarizer but reflects the light once by the brightness enhanced film, and further makes the light reversed through the reflective layer etc. prepared in the backside to re-enter the light into the brightness enhanced

film. By this above-mentioned repeated operation, only when the polarization direction of the light reflected and reversed between the both becomes to have the polarization direction which may pass a polarizer, the brightness enhanced film transmits the light to supply it to the polarizer. As a result, the light from a backlight may be efficiently used for the display of the picture of a liquid crystal display to obtain a bright screen.

The suitable films are used as the above-mentioned brightness enhanced film. Namely, multilayer thin film of a dielectric substance; a laminated film that has the characteristics of transmitting a linearly polarized light with a predetermined polarization axis, and of reflecting other light, such as the multilayer laminated film of the thin film having a different refractive-index anisotropy; an aligned film of cholesteric liquid-crystal polymer; a film that has the characteristics of reflecting a circularly polarized light with either left-handed or right-handed rotation and transmitting other light, such as a film on which the aligned cholesteric liquid crystal layer is supported; etc. may be mentioned.

Therefore, in the brightness enhanced film of a type that transmits a linearly polarized light having the above-mentioned predetermined polarization axis, by arranging the polarization axis of the transmitted light and

entering the light into a polarization plate as it is, the absorption loss by the polarization plate is controlled and the polarized light can be transmitted efficiently. On the other hand, in the brightness enhanced film of a type that transmits a circularly polarized light as a cholesteric liquid-crystal layer, the light may be entered into a polarizer as it is, but it is desirable to enter the light into a polarizer after changing the circularly polarized light to a linearly polarized light through a retardation plate, taking control an absorption loss into consideration. In addition, a circularly polarized light is convertible into a linearly polarized light using a quarter wavelength plate as the retardation plate.

A retardation plate that works as a quarter wavelength plate in a wide wavelength ranges, such as a visible-light region, is obtained by a method in which a retardation layer working as a quarter wavelength plate to a pale color light with a wavelength of 550 nm is laminated with a retardation layer having other retardation characteristics, such as a retardation layer working as a half-wavelength plate. Therefore, the retardation plate located between a polarization plate and a brightness enhanced film may consist of one or more retardation layers.

In addition, also in a cholesteric liquid-crystal layer, a layer reflecting a circularly polarized light in a wide

wavelength ranges, such as a visible-light region, may be obtained by adopting a configuration structure in which two or more layers with different reflective wavelength are laminated together. Thus a transmitted circularly polarized light in a wide wavelength range may be obtained using this type of cholesteric liquid-crystal layer.

Moreover, the polarization plate may consist of multi-layered film of laminated layers of a polarization plate and two or more of optical layers as the above-mentioned separated type polarization plate. Therefore, a polarization plate may be a reflection type elliptically polarization plate or a semi-transmission type elliptically polarization plate, etc. in which the above-mentioned reflection type polarization plate or a semitransparent type polarization plate is combined with above described retardation plate respectively.

The above-mentioned elliptically polarization plate and an above-mentioned reflected type elliptically polarization plate are laminated plate combining suitably a polarization plate or a reflection type polarization plate with a retardation plate. This type of elliptically polarization plate etc. may be manufactured by combining a polarization plate (reflected type) and a retardation plate, and by laminating them one by one separately in the manufacture process of a liquid crystal display. On the other hand, the

polarization plate in which lamination was beforehand carried out and was obtained as an optical film, such as an elliptically polarization plate, is excellent in a stable quality, a workability in lamination etc., and has an advantage in improved manufacturing efficiency of a liquid crystal display.

A pressure sensitive adhesive layer may also be prepared in an optical film of the present invention. A pressure sensitive adhesive layer may be used for attachment to liquid crystal cell, and also for laminating of an optical layer. In adhesion of the above-mentioned optical film, those optical axes may be adjusted so that they may give suitable configuration angle according to a desired retardation characteristics.

As pressure sensitive adhesive that forms adhesive layer is not especially limited, and, for example, acrylic type polymers; silicone type polymers; polyesters, polyurethanes, polyamides, polyethers; fluorine type and rubber type polymers may be suitably selected as a base polymer. Especially, a pressure sensitive adhesive such as acrylics type pressure sensitive adhesives may be preferably used, which is excellent in optical transparency, showing adhesion characteristics with moderate wettability, cohesiveness and adhesive property and has outstanding weather resistance, heat resistance, etc.

Moreover, an adhesive layer with low moisture absorption and excellent heat resistance is desirable. This is because



those characteristics are required in order to prevent foaming and peeling-off phenomena by moisture absorption, in order to prevent decrease in optical characteristics and curvature of a liquid crystal cell caused by thermal expansion difference etc. and in order to manufacture a liquid crystal display excellent in durability with high quality.

The adhesive layer may contain additives, for example, such as natural or synthetic resins, adhesive resins, glass fibers, glass beads, metal powder, fillers comprising other inorganic powder etc., pigments, colorants and antioxidants. Moreover, it may be an adhesive layer that contains fine particle and shows optical diffusion nature.

Proper method may be carried out to attach an adhesive layer to one side or both sides of the optical film. As an example, about 10 to 40 weight % of the pressure sensitive adhesive solution in which a base polymer or its composition is dissolved or dispersed, for example, toluene or ethyl acetate or a mixed solvent of these two solvents is prepared. A method in which this solution is directly applied on a polarization plate top or a optical film top using suitable developing methods, such as flow method and coating method, or a method in which an adhesive layer is once formed on a separator, as mentioned above, and is then transferred on a polarization plate or an optical film may be mentioned.

An adhesive layer may also be prepared on one side or

both sides of a polarization plate or an optical film as a layer in which pressure sensitive adhesives with different composition or different kind etc. are laminated together. Moreover, when adhesive layers are prepared on both sides, adhesive layers that have different compositions, different kinds or thickness, etc. may also be used on front side and backside of a polarization plate or an optical film. Thickness of an adhesive layer may be suitably determined depending on a purpose of usage or adhesive strength, etc., and generally is 1 to 500  $\mu\text{m}$ , preferably 5 to 200  $\mu\text{m}$ , and more preferably 10 to 100  $\mu\text{m}$ .

A temporary separator is attached to an exposed side of an adhesive layer to prevent contamination etc., until it is practically used. Thereby, it can be prevented that foreign matter contacts adhesive layer in usual handling. As a separator, without taking the above-mentioned thickness conditions into consideration, for example, suitable conventional sheet materials that is coated, if necessary, with release agents, such as silicone type, long chain alkyl type, fluorine type release agents, and molybdenum sulfide may be used. As a suitable sheet material, plastics films, rubber sheets, papers, cloths, non woven fabrics, nets, foamed sheets and metallic foils or laminated sheets thereof may be used.

In addition, in the present invention, ultraviolet

absorbing property may be given to the above-mentioned each layer, such as a polarizer for a polarization plate, a transparent protective film and an optical film etc. and an adhesive layer, using a method of adding UV absorbents, such as salicylic acid ester type compounds, benzophenol type compounds, benzotriazol type compounds, cyano acrylate type compounds, and nickel complex salt type compounds.

An optical film of the present invention may be preferably used for manufacturing various equipment, such as liquid crystal display, etc. Assembling of a liquid crystal display may be carried out according to conventional methods. That is, a liquid crystal display is generally manufactured by suitably assembling several parts such as a liquid crystal cell, optical films and, if necessity, lighting system, and by incorporating driving circuit. In the present invention, except that an optical film by the present invention is used, there is especially no limitation to use any conventional methods. Also any liquid crystal cell of arbitrary type, such as TN type, and STN type,  $\pi$  type may be used.

Suitable liquid crystal displays, such as liquid crystal display with which the above-mentioned optical film has been located at one side or both sides of the liquid crystal cell, and with which a backlight or a reflective plate is used for a lighting system may be manufactured. In this case, the optical film by the present invention may be installed in

one side or both sides of the liquid crystal cell. When installing the optical films in both sides, they may be of the same type or of different type. Furthermore, in assembling a liquid crystal display, suitable parts, such as diffusion plate, anti-glare layer, antireflection film, protective plate, prism array, lens array sheet, optical diffusion plate, and backlight, may be installed in suitable position in one layer or two or more layers.

Subsequently, organic electro luminescence equipment (organic EL display) will be explained. Generally, inorganic EL display, a transparent electrode, an organic luminescence layer and a metal electrode are laminated on a transparent substrate in an order configuring an illuminant (organic electro luminescence illuminant). Here, a organic luminescence layer is a laminated material of various organic thin films, and much compositions with various combination are known, for example, a laminated material of hole injection layer comprising triphenylamine derivatives etc., a luminescence layer comprising fluorescent organic solids, such as anthracene; a laminated material of electronic injection layer comprising such a luminescence layer and perylene derivatives, etc.; laminated material of these hole injection layers, luminescence layer, and electronic injection layer etc.

An organic EL display emits light based on a principle

that positive hole and electron are injected into an organic luminescence layer by impressing voltage between a transparent electrode and a metal electrode, the energy produced by recombination of these positive holes and electrons excites fluorescent substance, and subsequently light is emitted when excited fluorescent substance returns to ground state. A mechanism called recombination which takes place in a intermediate process is the same as a mechanism in common diodes, and, as is expected, there is a strong non-linear relationship between electric current and luminescence strength accompanied by rectification nature to applied voltage.

In an organic EL display, in order to take out luminescence in an organic luminescence layer, at least one electrode must be transparent. The transparent electrode usually formed with transparent electric conductor, such as indium tin oxide (ITO), is used as an anode. On the other hand, in order to make electronic injection easier and to increase luminescence efficiency, it is important that a substance with small work function is used for cathode, and metal electrodes, such as Mg-Ag and Al-Li, are usually used.

In organic EL display of such a configuration, an organic luminescence layer is formed by a very thin film about 10nm in thickness. For this reason, light is transmitted nearly completely through organic luminescence layer as through

transparent electrode. Consequently, since the light that enters, when light is not emitted, as incident light from a surface of a transparent substrate and is transmitted through a transparent electrode and an organic luminescence layer and then is reflected by a metal electrode, appears in front surface side of the transparent substrate again, a display side of the organic EL display looks like mirror if viewed from outside.

In an organic EL display containing an organic electro luminescence illuminant equipped with a transparent electrode on a surface side of an organic luminescence layer that emits light by impression of voltage, and at the same time equipped with a metal electrode on a back side of organic luminescence layer, a retardation plate may be installed between these transparent electrodes and a polarization plate, while preparing the polarization plate on the surface side of the transparent electrode.

Since the retardation plate and the polarization plate have function polarizing the light that has entered as incident light from outside and has been reflected by the metal electrode, they have an effect of making the mirror surface of metal electrode not visible from outside by the polarization action. If a retardation plate is configured with a quarter wavelength plate and the angle between the two polarization directions of the polarization plate and the retardation plate is adjusted

to  $\pi/4$ , the mirror surface of the metal electrode may be completely covered.

This means that only linearly polarized light component of the external light that enters as incident light into this organic EL display is transmitted with the work of polarization plate. This linearly polarized light generally gives an elliptically polarized light by the retardation plate, and especially the retardation plate is a quarter wavelength plate, and moreover when the angle between the two polarization directions of the polarization plate and the retardation plate is adjusted to  $\pi/4$ , it gives a circularly polarized light.

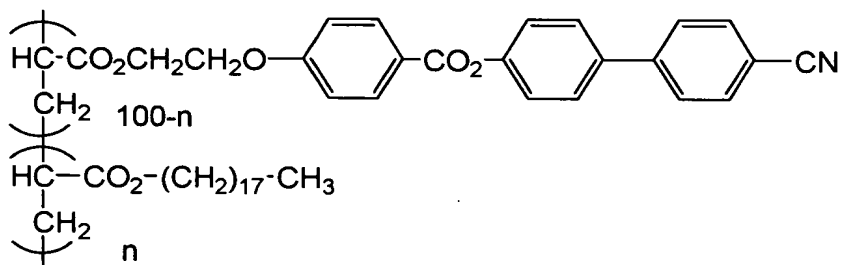
This circularly polarized light is transmitted through the transparent substrate, the transparent electrode and the organic thin film, and is reflected by the metal electrode, and then is transmitted through the organic thin film, the transparent electrode and the transparent substrate again, and is turned into a linearly polarized light again with the retardation plate. And since this linearly polarized light lies at right angles to the polarization direction of the polarization plate, it cannot be transmitted through the polarization plate. As the result, mirror surface of the metal electrode may be completely covered.

#### Example

Although an embodiment of the present invention is

explained using an example below, it goes without saying that the present invention may not be limited by the example.

#### Example 1



(where,  $n = 18$ , shows mole % of monomer unit, represented in block groups for convenience, weight average molecular weight = 5000) A solution of a side chain type liquid crystal polymer represented by above described formula 20 weight part dissolved in dichloroethane 80 weight part was coated on a plastics film ( $20 \mu\text{m}$ ) made of a polymer material of norbornene type resin (brand name Zeonor, by Zeon Corporation) using a spin coating method. Subsequently, after the coated film was heated for 1 minute at  $160^\circ\text{C}$ , it was cooled at a stretch to room temperature. The above-mentioned liquid crystal polymer layer was homeotropically aligned and vitrified while maintaining aligned state by this operation to obtain an alignment liquid crystal film with fixed homeotropic alignment liquid crystal layer ( $2 \mu\text{m}$ ).

When the sample (homeotropic alignment liquid crystal film with a substrate) was observed from perpendicular



direction to the film surface concerned using a polarization microscope with crossed Nicol polarizer, nothing was observed from front. This meant that homeotropic alignment was confirmed. That is, it turned out that an optical retardation had not occurred. Transmitted light was observed, when this film was leaned and observed by the crossed Nicol polarizer with incident light entered from oblique direction.

Moreover, optical retardation of this film was measured by automatic birefringence measurement equipment. Light measured is entered into the sample surface from vertical or oblique direction, and homeotropic alignment was confirmed from the optical retardation and a chart of the angle of incident light measured. In homeotropic alignment, a retardation (front retardation) in the vertical direction to sample surface gives almost zero. When retardation was measured from the oblique direction to the phase delay axis direction of liquid crystal layer for this sample, a retardation value increased with increase in the angle of incidence of measured light. This means that a homeotropic alignment was obtained.

#### Example 2

A homeotropic alignment liquid crystal film was manufactured as in Example 1 except that a norbornene type polymer (brand name Zeonex, by Zeon Corporation) was used as a polymer material of plastics film in Example 1.

Subsequently, homeotropic alignment of the sample obtained was confirmed as in Example 1.

#### Example 3

A homeotropic alignment liquid crystal film was manufactured as in Example 1 except that a norbornene type polymer (brand name ARTON, by JSR Corporation) was used as a polymer material of plastics film in Example 1. Subsequently, homeotropic alignment of the sample obtained was confirmed as in Example 1.

#### Example 4

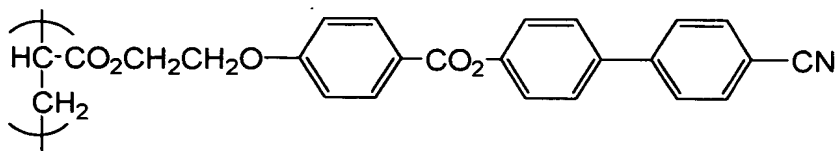
A homeotropic alignment liquid crystal film was manufactured as in Example 1 except that an aluminum foil (15  $\mu\text{m}$ ) was used as a substrate in Example 1 instead of the plastics film. Subsequently, homeotropic alignment liquid crystal film was transferred onto a cellulose triacetate film, and was separated from the substrate to obtain a sample film. Homeotropic alignment of the sample was confirmed as in Example 1.

#### Example 5

A homeotropic alignment liquid crystal film was manufactured as in Example 1 except that a glass substrate (1 mm) was used instead of the plastics film. Subsequently,

homeotropic alignment of the sample obtained was confirmed as in Example 1.

#### Comparative Example 1



The same operation as in Example 1 was repeated except that side a chain type liquid crystal polymer (weight average molecular weight 5000) represented by the above described formula as a material of liquid crystal layer in Example 1. Moreover, although the sample was evaluated as in Example 1, homeotropic alignment was not confirmed. The sample gave a white opaque color when observed from front side. This meant that the liquid crystal director faced to all directions and that the alignment of the liquid crystal was in disarrangement.

#### Example 6

A side chain type liquid crystal polymer shown in the Example 1 (where,  $n = 35$ , shows mole % of monomer unit, represented in block groups for convenience, weight average molecular weight = 5000) 12.5 weight parts; a photopolymerizable liquid crystal compound showing nematic liquid crystal property (PaliocolorLC242, by BASF A.G.) 12.5

weight parts; and five % of a photo polymerization initiator (Irgacure 907, by Ciba Specialty Chemicals) on the weight of the photopolymerizable liquid crystal compound were dissolved in cyclohexane 75 weight parts to obtain a solution. This solution was coated by spin coating method on a plastics film (20  $\mu\text{m}$ ) made of polymer material of norbornene type polymer (brand name Zeonex, by Zeon Corporation). Subsequently, after the coated film was heated for 1 minute at 130°C, it was cooled at a stretch to room temperature. The above described liquid crystal layer was homeotropically aligned and subsequently the homeotropic alignment liquid crystal layer obtained (2  $\mu\text{m}$ ) was fixed while maintaining aligned state. Furthermore, a homeotropic alignment liquid crystal film was obtained by irradiating ultraviolet to the fixed homeotropic alignment liquid crystal layer.

(Homeotropic alignment property)

When the sample (homeotropic alignment liquid crystal film with substrate) was observed from vertical direction to the film surface concerned using a polarization microscope with crossed Nicol polarizer, nothing was observed from front side. This meant that homeotropic alignment was confirmed. That is, it turned out that an optical retardation had not occurred. Transmitted light was observed, when this film was leaned and observed by the crossed Nicol polarizer with

incident light entered from oblique direction. Moreover, optical retardation of this film was measured by automatic birefringence measurement equipment. A value of 30 nm was obtained when measured from 30° of lefts.

(Durability evaluation)

Three durability evaluation test were carried out; heat-resistant evaluation test in which the sample (a homeotropic alignment liquid crystal film with substrate) was left to stand in 90°C drying furnace for 120 hours; heat and humidity evaluation test in which the sample was left to stand under conditions of 60°C / 90 % RH for 120 hours; and Heat-resistant of adhesion evaluation test in which a polarization film was attached onto the homeotropic alignment liquid crystal film through pressure sensitive adhesive and the laminated film obtained was left to stand in 90°C drying furnace for 2 hours. Physical properties of the sample before and after the test were compared. In any of the three tests, no change was observed at all before and after the tests.

Example 7

A homeotropic alignment liquid crystal film was manufactured as in Example 6 except that a norbornene type polymer (brand name ARTON, by JSR Corporation) was used as a polymer material of plastics film in Example 6. Moreover,

the homeotropic alignment property of the sample was confirmed as in Example 6. In addition, in any of the three above-mentioned durability tests, no change was observed at all before and after the tests.

#### Example 8

A homeotropic alignment liquid crystal film was manufactured as in Example 6 except that a glass substrate (1 mm) was used instead of a plastics film as a substrate in Example 6. In addition, the homeotropic alignment of the sample was confirmed as in Example 6. Moreover, in any of the three above-mentioned durability tests, no change was observed at all before and after the tests.

#### Example 9

A homeotropic alignment liquid crystal film was manufactured as in Example 6 except that in Example 6 the amount of the side chain type liquid crystal polymer used was changed into 2.5 weight parts, the amount of the photopolymerizable liquid crystal compound used was changed into 22.5 weight parts, and a glass substrate (1 mm) was used instead of a plastics film as a substrate. In addition, the homeotropic alignment of the sample was confirmed as in example 6. Moreover, in any of the three above-mentioned durability tests, no change was observed at all before and after the

tests.

#### Referential Example 1

A homeotropic alignment liquid crystal film was manufactured as in Example 6 except that a photopolymerizable liquid crystal compound and a photo polymerization initiator were not used and only the side chain type liquid crystal polymer 25 weight parts was used in Example 6. In addition, the homeotropic alignment of sample was confirmed as in Example 6. However, in any of the three durability tests, some change of disarrangement etc. of alignment was confirmed after the tests.